CLAIMS

1. Method for estimating the movement between two numerical images I_1 and I_2 with luminance Y_1 and Y_2 for generating for each point of coordinates x,y of the image I_2 a movement vector $\vec{d}(x,y)=(d_x,d_y)$ so as to form an image $\hat{I}_2$ from the image I_1 with luminance $\hat{Y}_2(x,y)=Y_1(x-d_x,y-d_y)$ which is an approximation of the image I_2, characterised in that it comprises the following steps :

(a) defining an initial model of finished elements comprising a meshing whose nodes are points of the image I_2, a movement vector at each node of said meshing, and an interpolation formula for calculating the value of the movement vector of each point of the image I_2 from the values of the movement vectors of the nodes of the mesh to which it belongs,

(b) globally optimising the values of all the movement vectors of the model according to a differential method,

(c) calculating a variation E between the image $\hat{I}_2$ and the image I_2 for each finished element or mesh,

(d) carrying out a finer meshing on a discrete fraction of all the finished elements determined according to a criterion relating to the variations E and allocating a movement vector to each new meshing node,

(e) repeating the steps (b), (c) and (d) on the model of finished elements obtained at the end of the preceding step (d) until a stoppage criterion is satisfied.

2. Method according to claim 1, characterised in that, so as to carry out a finer meshing on a discrete fraction of all the finished elements in step (d), said set of finished elements is classified in the decreasing order of their variations E and the X first finished elements of this classification are subdivided into smaller finished elements, X representing a predetermined fraction of the number of finished elements of the set.

3. Method according to claim 1, characterised in that, so as to carry out a finer meshing on a discrete fraction of the set of finished elements in step (d), the set of variations E calculated in step (c) is compared with a threshold variation which

depends on the size of the finished element in question, and the finished elements whose variations E are greater than the threshold variation are subdivided into smaller finished elements.

4. Method according to ~~one of~~ claim~~s~~ 1 ~~to 3~~, characterised in that said stoppage criterion is a predetermined number of finished elements constituting the model of finished elements to be reached at the end of step (d).

5. Method according to ~~one of~~ claim~~s~~ 1 ~~to 3~~, characterised in that said stoppage criterion of step (e) is satisfied when the variations E of the set of finished elements of the model obtained at the end of the preceding step (d) are smaller than a functional threshold variation which depends on the size of the finished elements in question.

6. Method according to ~~one of~~ claim~~s~~ 1 ~~to 5,~~ characterised in that in addition for each numerical image I_1 and I_2, a set of R images I_i^r with a level of resolution r and luminance Y_i^r with r taking the values (0,....R-1) and i the values 1 and 2 is defined, the images I_1^0 and I_2^0 corresponding to the numerical images I_1 and I_2, and in that the steps (b) to (e) are carried out for each resolution level r from the level r=R-1 to the level r=0.

7. Method according to claim 6, characterised in that the sets of R images with resolution level r are obtained by filtering the images I_1 and I_2 along the two directions x and y using a low-pass filter with a pulse response h_n^r , each image I_i^r being defined by the following equation :

$$Y_i^r(x,y) = \sum_{u=-M}^{M} \sum_{v=-M}^{M} Y_i(x-u, y-v) h_u^r h_v^r$$

with M a natural integer.

8. Method according to claim 7, characterised in that the pulse response h_n^r is defined as follows :

$$h_n^r = \frac{s_n^r}{S} \quad \text{avec} \quad S = \sum_{n=-M}^{M} s_n^r$$

$$s_n^r = 2B.\operatorname{sinc}(2\pi B_r n) = 2B\frac{\sin 2\pi B_r n}{2\pi B_r n}$$

$$B_r = \frac{1}{2^{r+1}}$$

B being a natural integer.

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9. Method according to ~~one of the preceding claims,~~ claim 1 characterised in that the initial movement vectors are nil vectors.

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10. Method according to ~~one of the preceding claims,~~ claim 1 characterised in that the variation E between the image $\hat{I}_2$ and the image I_2 for each finished element e is defined by the following equation :

$$E = \sum_{(x,y)\in e} DFD^2(x,y)$$

where $DFD(x,y) = Y_2(x,y) - Y_1(x-d_x, y-d_y)$

11. Method according to ~~one of the preceding claims,~~ claim 1 characterised in that the interpolation formula for calculating the value of the movement vector of a point P of coordinates (x,y) in the image I_2 belonging to the finished element e with vertices P_i, P_j and P_k with respective coordinates (x_i,y_i), (x_j,y_j) et (x_k,y_k) is the following :

$$\vec{d}(x,y) = \sum_{l=i,j,k} \Psi_l^e(x,y).\vec{d}(x_l,y_l)$$

where ψ_l is a function of the form

$$\begin{cases} \begin{cases} \Psi_l(x,y) = \alpha_l + \beta_l x + \gamma_l y & (x,y) \in e \\ \sum_{l=i,j,k} \Psi_l(x,y) = 1 & \end{cases} \\ \Psi_l(x,y) = 0 & (x,y) \notin e \end{cases}$$

12. Method according to ~~one of~~ claim~~s~~ 1 ~~to 11,~~ characterised in that the differential method for optimising the movement vectors is the Gauss-Newton method.

13. Method according to ~~one of~~ claim~~s~~ 1 ~~to 11,~~ characterised in that the differential method for optimising the movement vectors is the Marquardt extension of the Gauss-Newton method.

14. Method according to claim 1 ~~one of the preceding claims,~~ characterised in that a compactness constraint is imposed on each finished element at the time of optimising the movement vectors of the model of finished elements, said constraint consisting of preventing the compactness of each finished element from tending to zero.

15. Method according to claim 14, characterised in that the compactness constraint on a finished element e with vertices P_i, P_j, P_k and compactness C (P_i,P_j,P_k) is defined by the following equation :

$$C\left(P_i+\vec{d}_{P_i},P_j+\vec{d}_{P_j},P_k+\vec{d}_{P_k}\right)\geq K\times C\left(P_i,P_j,P_k\right)$$

where $\vec{d}_{P_i}$, $\vec{d}_{P_j}$, et $\vec{d}_{P_k}$ represent the movement vectors of the vertices P_i, P_j, P_k during the optimisation step, and K is a compactness parameter.

16. Method according to claim 14 ~~or 15,~~ characterised in that the optimisation of the movement vectors under constraints on the finished elements is resolved by the increased Lagrangian technique.

17. Method according to claim 16, characterised in that the constraints are used in a linearised form in the increased Lagrangian technique.

18. Method according to ~~one of~~ claim~~s~~ 1 ~~12, 13 or 17~~, characterised in that the methods for optimising the movement vectors use an LDL^t profile technique.

19. Application of the method for estimating movement between two numerical images according to ~~one of~~ claim~~s~~ 1 ~~to 18~~ for coding images, characterised in that the fractional subdivision of the meshing carried out in step d) of the movement estimation method is associated with a partially quaternary tree in which each level represents a meshing level and each node represents a triangle of the given level, and in that what is generated is a binary train describing said tree.

20. Application of the method for estimating movement between two numerical images according to claim 19, characterised in that the movement vectors associated with each node of said tree are encoded differentially with respect to the movement vectors of their father node when the latter exists and are ordered in said binary train along a width passage of said tree.

21. Application of the method for estimating movement between two numerical images according to ~~one of~~ claim~~s~~ 1 ~~to 18~~ for decoding images, characterised in that the fractional subdivision of the meshing carried out in step d) of the movement estimation method is associated with a partially quaternary tree in which each level represents a meshing level and each node represents a triangle of the given level, and in that said tree is generated from a binary train of encoded data describing said tree.

22. Application of the method for estimating movement between two numerical images according to claim 21, characterised in that the encoded data relating to a given level of the tree are collectively regrouped in the binary train so as to generate the tree level by level as the train is read.

23. Application of the method according to claim 1 ~~one of the preceding claims~~ to at least one of the ranges belonging to the group of the following ranges :

- compression of sequences of images, and
- compression of data in spaces larger than 2.